## Diodes

Logic gates cannot handle negative voltages at their inputs, so the output of an op-amp cannot be fed directly into one. A diode is necessary to only let positive voltages through, as shown in Fig. 2.13.

Fig 2.13 Charge only flows through the diode when it has forward bias.

Remember:
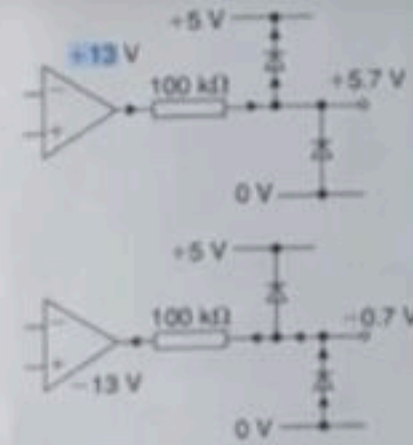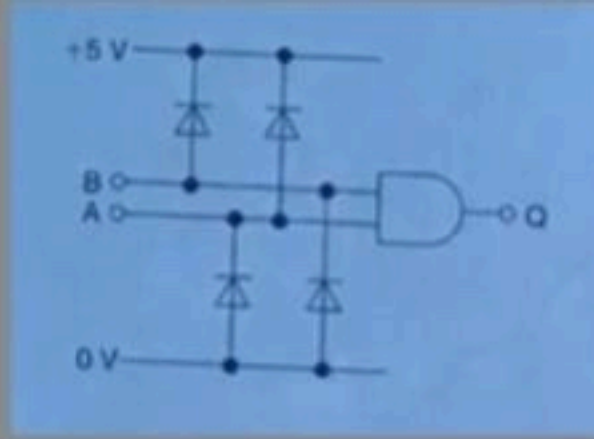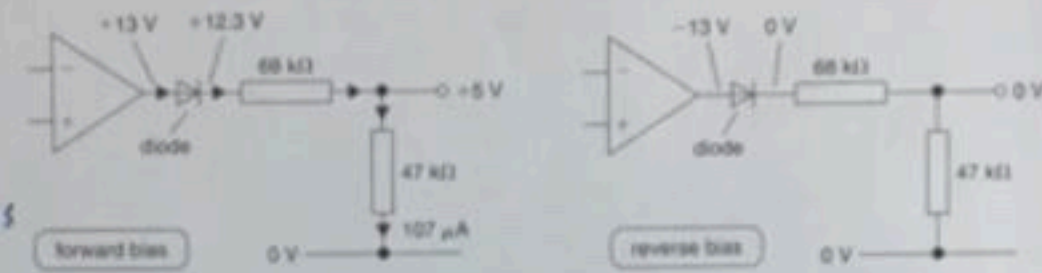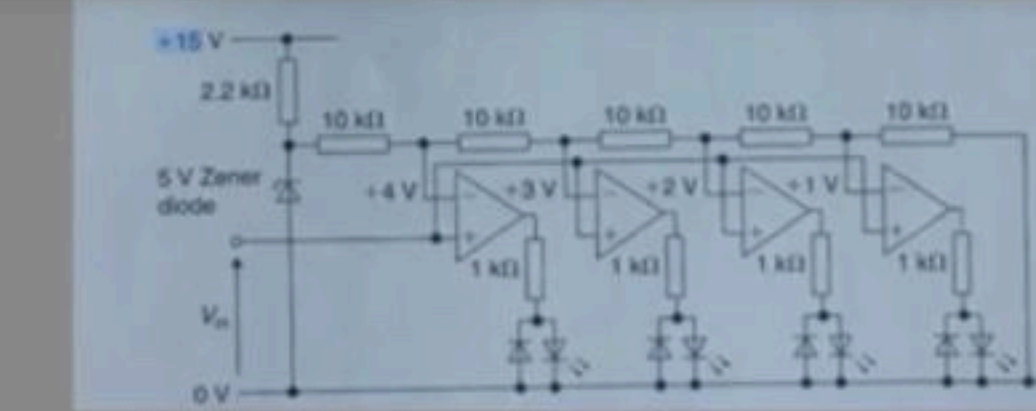The Diode takes 0.7 V.

forward bias

reverse bias

Fig 2.15 One diode is always in forward bias, clamping the output voltage close to the supply voltage.

The Zener diode generates a fixed +5 V from the +15 V supply (for details see the next page). Five 10 kΩ resistors make a resistor ladder which generates voltages of +4 V, +3 V, +2 V and +1 V. Each of the four op-amps compares the incoming signal $V_{in}$ with one of these four fixed voltages. If $V_{in}$ is greater than the voltage at an non-inverting input, the output of an op-amp saturates at +13 V, putting the LED in forward bias and making it glow. The silicon diode in parallel with each LED clamps the reverse bias voltage to −0.7 V: well below the breakdown voltage of −5 V for a typical LED.



A — AND — Q

| A | B | Q |
|---|---|---|
| 0 | 0 | 0 |
| 0 | 1 | 0 |
| 1 | 0 | 0 |
| 1 | 1 | 1 |

A — OR — Q

| A | B | Q |
|---|---|---|
| 0 | 0 | 0 |
| 0 | 1 | 1 |
| 1 | 0 | 1 |
| 1 | 1 | 1 |

A — NOR — Q

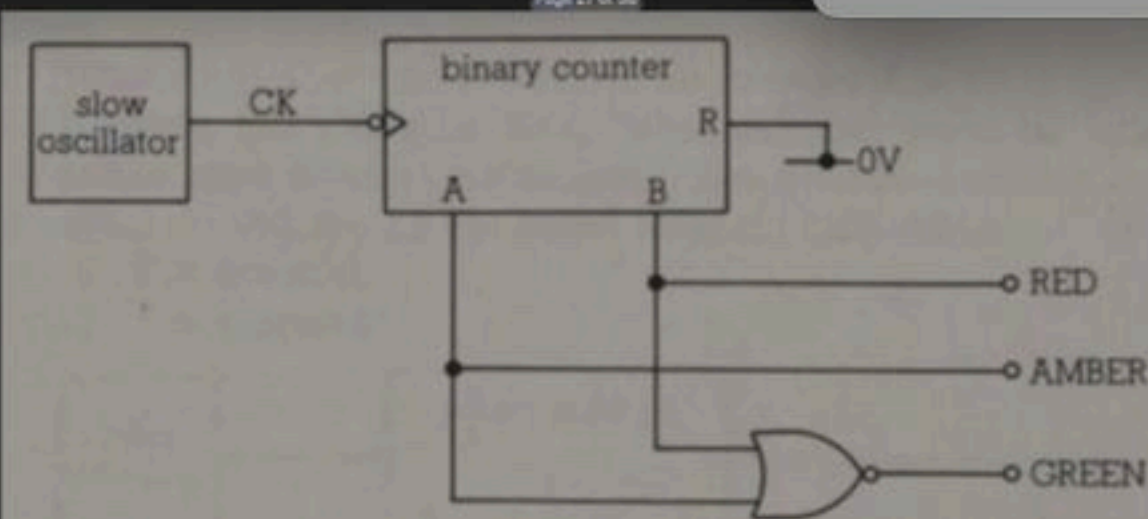| A | B | Q |
|---|---|---|
| 0 | 0 | 1 |
| 0 | 1 | 0 |
| 1 | 0 | 0 |
| 1 | 1 | 0 |

A — NAND — Q

| A | B | Q |
|---|---|---|
| 0 | 0 | 1 |
| 0 | 1 | 1 |
| 1 | 0 | 1 |
| 1 | 1 | 0 |

## Double Angle Formulas

$$\sin 2\theta = 2\sin\theta\cos\theta$$
$$\cos 2\theta = \cos^2\theta - \sin^2\theta$$
$$= 2\cos^2\theta - 1$$
$$= 1 - 2\sin^2\theta$$
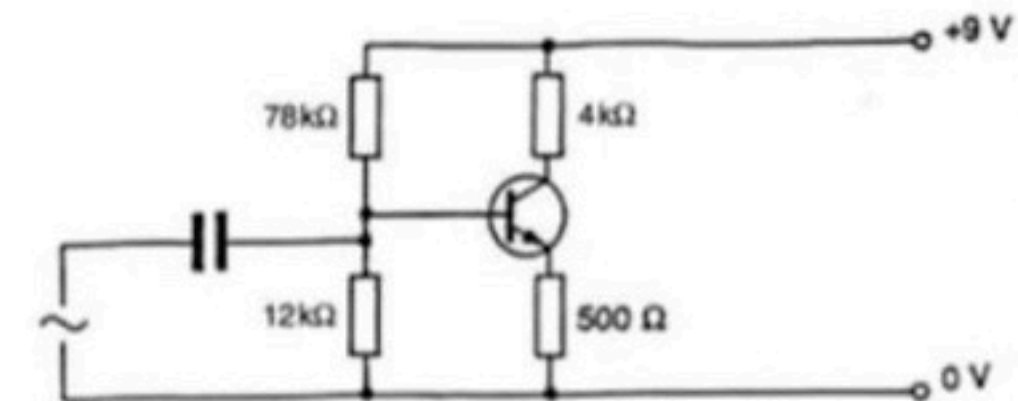$$\tan 2\theta = \frac{2\tan\theta}{1 - \tan^2\theta}$$

## Half Angle Formulas

$$\sin^2\theta = \frac{1 - \cos 2\theta}{2}$$
$$\sin\frac{\theta}{2} = \pm\sqrt{\frac{1 - \cos\theta}{2}}$$
$$\cos^2\theta = \frac{1 + \cos 2\theta}{2}$$
$$\sin\frac{\theta}{2} = \pm\sqrt{\frac{1 + \cos\theta}{2}}$$
$$\tan\frac{\theta}{2} = \pm\sqrt{\frac{1 - \cos\theta}{1 + \cos\theta}}$$

slow oscillator — CK — binary counter

RED, AMBER, GREEN

| B | A | RED | AMBER | GREEN |
|---|---|-----|-------|-------|
| 0 | 0 | 0 | 0 | 1 |
| 0 | 1 | 0 | 1 | 0 |
| 1 | 0 | 1 | 0 | 0 |
| 1 | 1 | 1 | 1 | 0 |

For a given mass of gas, the volume, $V\,cm^3$, and pressure, $p\,cm$ of mercury, are related by $p = kV^n$ where $k$ and $n$ are constants.

(a) Prove that $\dfrac{dp}{dV} = \dfrac{np}{V}$

## 2

The circuit of Fig. 2.1 shows a fully stabilised voltage amplifier. The transistor has a d.c. current gain ($h_{fe}$) of 100.
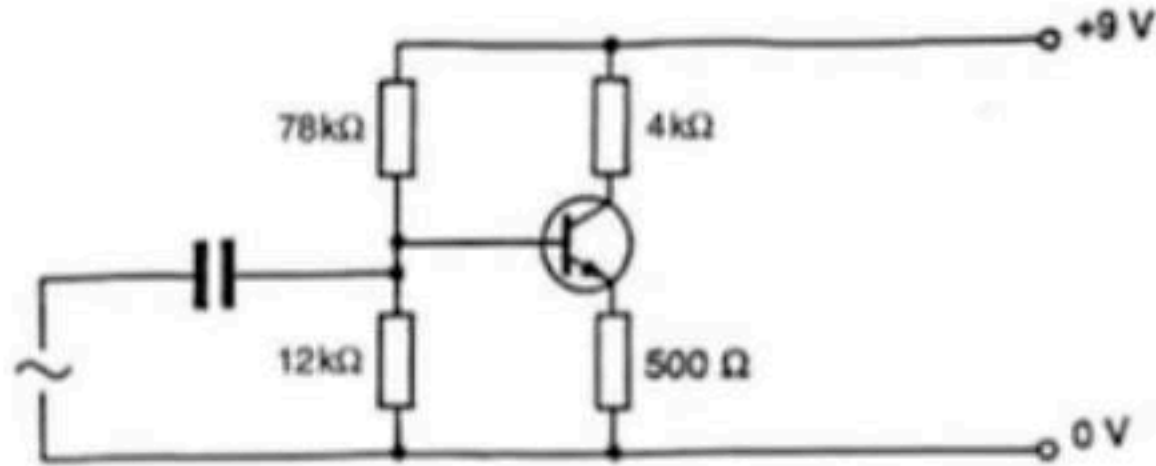


**Fig. 2.1**

(a) Calculate the voltage at the base.

(b) Calculate the emitter current.

$$9 - ((0.3 / 0.5) * 4) = $$

$$6.6$$

(c) Calculate the voltage of the collector.

(d) A sinusoidal input signal of frequency 1 kHz and peak value 200 mV is now applied to the base via a capacitor. Draw two sketch graphs of the voltages on the base and collector as functions of time for two cycles of the input. Label the graphs. [3]
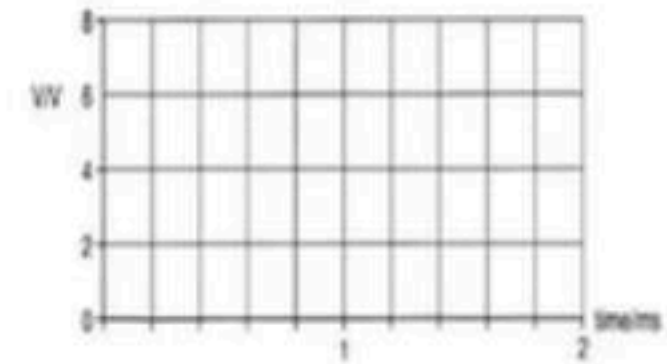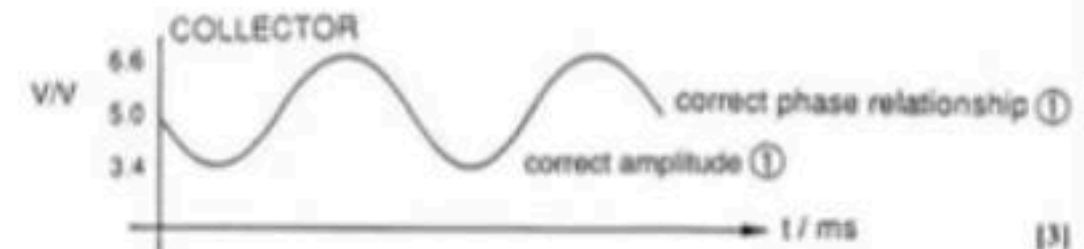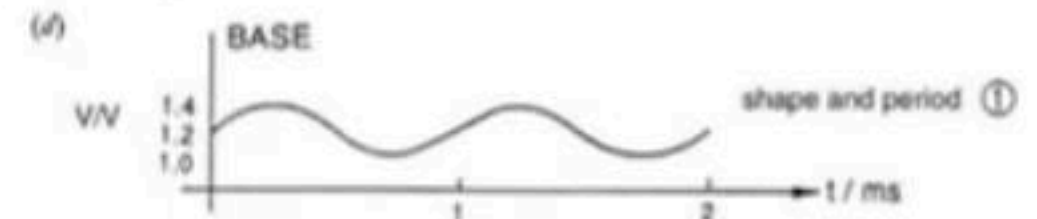


**Fig. 2.2**

[Total: 8]

(a) $V_{base} = \dfrac{12}{12 + 78} \times 9 = 1.2\ V$ [1]

(b) $I_e = \dfrac{1.2 - 0.7}{0.5} = 1\ mA$ [1]

(c) $V_c = 9 - I_c R_c = 9 - 1 \times 4 = 5\ V$ [2]
   [1]  [1]

(d)



BASE — shape and period ①

COLLECTOR — correct phase relationship ① correct amplitude ① [3]

**Note:**
The current gain formula is valid **only** in the linear region. However, it can be used right up to the point where the transistor enters saturation. Examination questions are worded in the following or similar manner:

Determine the value of $V_{in}$ that will cause the transistor **just** to saturate.

or     The transistor is **just** saturated when the input voltage $V_{in} = 2.5$, etc.

This phraseology allows the equation to be used.

Simplify the following expressions.

2. $\dfrac{1 - \sec^2 A}{1 - \operatorname{cosec}^2 A}$

4. $\dfrac{\sin \theta}{\cos \theta} + \dfrac{\cos \theta}{\sin \theta}$

6. $\dfrac{1}{\cos \theta \sqrt{(1 + \cot^2 \theta)}}$

3. $\dfrac{\sin \theta}{\sqrt{(1 - \cos^2 \theta)}}$

5. $\dfrac{\sqrt{(1 + \tan^2 \theta)}}{\sqrt{(1 - \sin^2 \theta)}}$

7. $\dfrac{\sin \theta}{1 + \cot^2 \theta}$

2. $\tan^4 A$
3. $1$
4. $\sec \theta \operatorname{cosec} \theta$
5. $\sec^2 \theta$
6. $\tan \theta$
7. $\sin^3 \theta$

$$\sec^2 A = 1 + \tan^2 A$$

$$\csc^2 A = 1 + \cot^2 A$$

$\dfrac{2 + 2\cos(A)}{(1 + \cos(A)) \cdot \sin(A)}$

Factor out 2 from the expression

$\dfrac{2(1 + \cos(A))}{(1 + \cos(A)) \cdot \sin(A)}$

$\dfrac{\frac{1}{\sin A}}{\frac{\cos A}{\sin^2 A}}$

$\dfrac{2(1 + \cos(A))}{(1 + \cos(A)) \cdot \sin(A)}$

Cancel out the common factor $1 + \cos(A)$

$\dfrac{2}{\sin(A)}$

$\dfrac{\frac{1}{\cos^2 A}}{\cos^2 A} \quad \dfrac{\tan A}{\frac{\cos A}{\sin A}}$

Simplify the complex fraction:

$\dfrac{1}{\sin A} \cdot \dfrac{\sin^2 A}{\cos A}$

$\dfrac{\sin^2 A}{\sin A \cos A}$

$\dfrac{\sin A}{\cos A}$